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54.   Fine metal-metal and/or metal-semimetal multilayer composites.

57.　　The invention relates to fine multilayer composites comprising at least two adjacent layers A-B each consisting of a pure element A or B or of an alloy AA', BB' such that: (a) the enthalpy of mixing of the elements or alloys present respectively in the adjacent layers, H_m, is negative, (b) H_m-H_F = Cp Δ T, in which H_F is the heat of fusion, Cp is the molar thermal capacity and Δ T = T_{max} − T^B_F where T^B_F is the melting point of the element B having the lowest melting point and T_{max} being the maximum temperature obtained due to the amount of heat available,　　(c) the mixing time t_m is substantially less than the heat dissipation time.

The compositions can be used in particular as thermal primers, short-circuit fuses and welding alloys.

Fine metal-metal and/or metal-semimetal

multilayer composites

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The present invention relates to fine metal-metal
and/or metal-semimetal multilayer composites and to their
application to ultra-rapid heating by release of the heat
of mixing.

It is known that when the atoms of two elements A
and B exhibit a strong positive heteroatomic interaction
A-B, their mixture is accompanied by an exothermic
reaction releasing an amount of heat termed "enthalpy of
mixing" H_m that corresponds to the energy difference
between the A-A bonds and B-B bonds in the pure bodies
and the predominance of more stable A-B bonds in the
mixed state.

This heat of mixing is released in the two cases of
mixing of the solid states or liquid states of A and B.

In the solid state A-B corresponding to certain
proportions of A and B, the mixing gives rise to the
formation of defined compounds of the type A_nB_m with heats
of formation H_{AB}. In the case of strong positive
interactions between A and B, that is to say a high value
of the enthalpy of mixing H_m, most of the heat comes from
the replacement of the atomic bonds A-A and B-B by the
bonds A-B and not from their ordered arrangement in any
crystalline structure.

The inventors have found that the kinematics of
release of H_m are controlled by the kinematics of the

mixing, which is itself controlled by the interatomic diffusion and the penetration of A into B or B into A.

The kinematics of mixing are more particularly characterised by a coefficient of atomic diffusion D_{AB} and a penetration distance X, which is a function of time such that $X^2 \cong D_{AB}t$, t being the mixing time.

As a result, for a thickness e of a layer of the element A or of the element B, we have a mixing time less than e^2/D_{AB}

that is to say:

$$t_m \lesssim \frac{e^2}{D_{AB}}$$

The inventors have found that the total mixing time of A and B and thus the time of release of the heat H_m of mixing was of the order of t $<\approx 10^2$sec when the temperature acting on the pair AB was between the melting point of the element B and the melting point of the element A, corresponding to the relationship

$$T^B_f \leq T_f < T^A_f$$

for a thickness of the layer of the order of 1 mm heated *in vacuo*, while

$$t > 10^5s \text{ when } T < T^B_f$$

that is to say the heat of mixing H_m is released over a time of the order of 1 minute at

$$T^B_f \leq T_f < T^A_f$$

and over several hours, days or even a month for the solid pair

when

$$T_f < T^B_f$$

It is understood that the mixing time should furthermore be significantly less than the dissipation time of the released heat. In other words, the following relationship should apply:

$$t_m = \frac{e^2}{D} \quad \ll \quad t_{diss} \approx f\left[\bar{k} \ (T_{ech.} - T_{env.})\right]$$

where k is a coefficient of conductivity, T_{ech} is the temperature of the sample, and T_{env} is the ambient temperature.

Finally, and provided that the loss of heat by the surroundings during the mixing is negligible, that is to say $t_m \ll t_{diss}$, the enthalpy of mixing and the heat of fusion should be connected by the relationship

$$H_m - H_f = Cp \ \Delta T$$

where H_f is the heat of fusion equal to the sum

$$n_A \ H^A_f + n_B \ H^B_f$$

where H^A_f and H^B_f are the amounts of heat that have to be supplied to n_A or n_B moles of elements A and B in order to melt them.

Cp is the molar heat capacity and

ΔT is equal to $T_{max} - T^B_f$ where T^B_f is the lowest melting point.

This relationship expresses the amount of heat available for a superheating to a temperature T_{max}.

On the basis of these findings the inventors have made available fine metal-metal and/or metal-semimetal multilayer composites.

The fine multilayer composites in accordance with the invention are basically characterised by the fact

that they comprise at least two adjacent layers A-B each consisting of a pure element or of an alloy AA', BB' such that

a) the enthalpy H_m of mixing of the elements or alloys present respectively in the adjacent layers is negative

b) $H_m - H_f = Cp\ T$

where H_f, Cp, T, have the meanings defined above

c) the mixing time t_m is substantially less than the heat dissipation time.

The thickness of the individual layers is preferably less than or equal to 150 μm.

The value of H_m can be determined by known methods such as the method of MIEDEMA (CALPHAD 1 pages 341-352 or Symposium "Theory of alloy phase formation" American Metallurgical Society Meeting 1979 New Orleans).

Particularly preferred composites in accordance with the invention are composites comprising at least two adjacent layers, one layer consisting of atoms of metals chosen from the noble metals and the transition metals such as for example Co, Ni, Cu, Zn, Pd, Ag, Pt, Au, and the other layer consisting of metals chosen from In, Tl, Sn, Pb, Al, Zn, the alkali metals Zr, Ti, the lanthanides and the actinides such as La, Ce, Y, U, Gd …. The adjacent layers may also consist of alloys consisting respectively of solid solutions of elements belonging to one or other of the classes of type A and B. It is also possible to use in two adjacent layers the elements specified above in the same family, provided that the conditions relating to H_m defined above are observed. Thus, one can envisage composites of the type Pd-Zn.

The composites in accordance with the invention can also be defined in terms of composites of multilayers A-

B, which can denote in particular not only two-layer composites A-B but also multilayers with more elements such as ABCDABCD or BABCBAB (periodic multilayers) or non-periodic multilayers such as BABCABAB, the third and fourth layer in these examples consisting of materials involved or otherwise in the mixing during the course of the heating.

In accordance with the invention one can for example prepared a multilayer composite of the type ABC BA where the layer C consists of a material that is inert to the product B at least up to the A-B mixing temperature, wherein the release of the heat H_m during the mixing of the layers A-B can serve to heat the layer C very rapidly.

In the case of alloys, the term multilayer A-B can denote multilayer composites of the type $(A_nA'_m)$ B $(A_nA'_m)$ B or, more generally, $(A_nA'_m)$ $(B_pB'_l)$ C $(A_nA'_m)$ $(B_pB'_l)$ …. In this type of composites the expression $A_nA'_m$ or $(B_pB'_l)$ denotes solid solutions of at least two elements A and A' or also B and B' present in molar proportions n,m,p, or l.

The alloys have the advantage of being able to adjust the temperature T_f to a specific value that is a function of the nature of the alloy employed.

The layers in accordance with the invention do not necessarily have the same thickness, and preferably have a thickness between 0.1 μm and 150 μm regardless of the preparation method that is used. This small thickness e of the layer does not impose any restrictions either on the overall thickness or on the width or length of the product, which can be of the order of millimetres, centimetres or more.

The term "layer" is defined as the thickness in the direction of penetration, that is to say perpendicular to the interface of the contact A−B, and does not restrict the dimensions of the interface, which are often larger than e. One can thus have superposed thin sheets of A and B or small particles of any arbitrary shape (sphere, disc … etc.) of A in a matrix of B, or vice versa.

One of the forms that is particularly used is obtained by compressing a sandwich or stratified arrangement A−B of strips 1 cm wide and 30 to 100 μm thick prefabricated by impregnating the strips with liquid on a cooling roller.

The composites in accordance with the invention can be prepared:

− by spray atomisation or successive and repeated vapour depositions of the constituent elements or alloys;

− by successive and repeated chemical deposition or electrodeposition of fine layers of selected elements;

− by co-lamination or co-extrusion of bars, threads or strips of selected elements or selected alloys;

− by compaction of fine powders of selected elements or alloys, wherein the powders can be prepared for example by atomisation processes or spray coating of liquid jets.

The composites in accordance with the invention as mentioned above should be such that they have a sufficiently large enthalpy of mixing H_m that is released sufficiently quickly. The melting of the multilayers consumes an amount of heat equal to the heat of fusion $H_f = Nh_f^A + m H_f^B$ where m and n are the molar fractions of the components A and B and H_f^A and H_f^B are the heats of fusion such that H_m of AB is greater than $n H_f^A + m H_f^B$.

The ultra-rapid release of the heat of mixing H_m in the fine multilayer polymetallic compositions according to the invention can be used in particular in the production of primers or fuses or in welding alloys, which are the principal applications envisaged by the invention.

In the use as a thermal primer the elements should be chosen so that the enthalpy of mixing H_m is greater than the overall heat of fusion H_f of the multilayers. Furthermore the released enthalpy of mixing H_m should be sufficiently larger than H_f so as to superheat the product and compensate for the heat lost to the surroundings during the mixing reaction. In addition the thickness of the layers e should be sufficiently small so as to obtain a mixing time t that is significantly less than the cooling time t_r due to heat loss to the surroundings.

The thickness of the layers of the composite product can be reduced if the primer is intended for use involving thermal contact with conducting substrates, compared to the use in a gaseous medium or *in vacuo*. The layers can also be thinner for high melting point primers requiring a high initiation temperature compared to primers having an initiation melting point close to the ambient temperature. The loss of heat to the surroundings is proportional to the difference T_f-T_a, where T_f is the melting point and T_a is the ambient temperature. These composites can also be used to prime other reactions such as chemical reactions in a heterogeneous medium.

The composites in accordance with the invention can also be used as short-circuit fuses either with the principal electrically conducting element such as for example copper or silver, which can form one of the two

types of layers A or B in the multilayer composite and thus participate in the initiation of the exothermic mixing, or with the principal conducting element sandwiched between the layers A-B such as the layers C in a structure of the type A-B-C-B-A-BC-BA, so that the exothermic mixing of A and B accelerates the heating due to the current and the Joule effect in the conductor C.

It is known that under normal operational conditions the heating of an electrically conducting material by the Joule effect of the passage of current I_0 is compensated by its cooling due to loss of heat to the surroundings, so that it reaches a quasi-constant temperature in the stationary state of the conditions of use. The fuse should be stable at this temperature so as to ensure a long service life.

The heat released by the Joule effect is given by the relationship

$$P = (\frac{I}{A})^2 \rho \quad J/s \; cm^3$$

in which I is expressed in amps and ρ is the resistivity in Ω cm and A is the cross-section of the conductor.

In normal operation the ratio $(I = I_0)/A$ is often of the order of 10^4 A/cm^2 and the resistivity is for example of the order of 1.6 $\mu\Omega$ cm for good conductors such as silver. The heat p released per mole of conductor is thus

$$P = (\frac{I}{A})^2 \rho \; \frac{M}{d} \quad J/s \; mole.$$

where M is the molar mass of the conductor and d is its density. For silver $\frac{M}{d}$ is for example equal to

10 cm^3/mole. The heat released for a current density I_0/A
= 10^4 amps/cm^2 and is thus of the order of 1672 J/mole.s.

When the current I exceeds the normal current I_0, the
heat released increases as the square of I assuming that
the resistivity remains constant. In order for the fuse
to protect the circuit it thus has to operate so that it
interrupts the circuit when I/I_0 increases.

For example, at I/I_0 = 50 the fuse should melt and
possibly vaporise in a time of the order of a tenth of a
millisecond. The heat released for a constant
resistivity for I/I_0 = 50 is 2500 times greater than that
released for I/I_0 = 1, of the order of 1672 J/mole.s, and
is thus of the order of 4.18 x 10^6 J/mole.s. Integrating
this output over a cut-off time of 10 milliseconds we
obtain a total amount of heat H_j released by the Joule
effect of the order of 4.18 x 10^4 J/mole, which is of the
order of the heat of mixing H_m per mole of the fine
multilayer polymetallic composite materials according to
the invention.

The inventors have also found that once the mixing
has been initiated, the mixing time t_m is a few
milliseconds, which is comparable to the cut-off time of
the fuses. It is understood of course that the value
specified above for H_j is an approximate value given
purely by way of example, and there exists a very large
range of fuses that can satisfy the various requirements.
It should also be noted that the resistivity varies
depending on the temperature.

An estimate of H_j is however useful for comparison
with the enthalpy of mixing H_m of the fine multilayer
composites. One can in fact choose materials of
composites having an enthalpy of mixing that is less than
or greater than H_j. The inventors have found that if H_m

and H_j are of the same order of magnitude this enables the cut-off time to be greatly accelerated by using the composites according to the invention as fuses. In fact the enthalpy of mixing will replace a large proportion of the heat H_j provided by the Joule effect.

Thus, in accordance with the invention the principal current conducting material can either be the material of type A or type B in the binary multilayer composite, or a supplementary layer C in a multilayer composite of type ABCBABC or also ABCABC, etc.

If a good conductor is required that is stable at a temperature of several tens of degrees centigrade in air, layers of materials such as silver or copper can be incorporated in the composites, such as for example a composite of the type Cu-Zr where the principal conductor Cu participates in the mixing or also a composite of the type Zn-Pd-Ag-Pd-Zn or also Sn-Pd-Ag-Pd-Sn-Pd-Ag where Ag does not participate in the initiation of the mixing but is instead heated and melted by the mixing on account of the exothermic enthalpy of mixing.

It is understood that a suitable combination of materials and layer thickness can be chosen depending on the requirements of the circuit, the desired triggering temperature, etc.

The composites in accordance with the invention can serve both as a thermal fuse and as a protection in the event of fire. For example, a composite consisting of fine multilayers can be placed on top of a thick conducting sheet such as of silver or copper. In the case of an electrical fault such as a short-circuit it is the fuse element that will interrupt the current, whereas if the ambient temperature rises to the melting point of the element of the multilayer composite having the lowest

melting point, on account of a fire for example, it is the composite product that interrupts the circuit by rapid release of its heat.

Another application of composites according to the invention is their use in welding. In fact, as has been mentioned above, the fine multilayer composites according to the invention permit the release of the highly exothermic heat of mixing H_m so as to propagate a self-melting front through the composite product once the mixing reaction has been initiated.

If the composites of the invention are used as welding materials they accelerate the welding process by the enthalpy of mixing H_m, which maintains a complete and rapid melting of the welding metal by providing the heat of fusion H_f. In the prior art the heat of fusion had to be supplied by the surroundings. In accordance with the invention the melting of the composite product can be initiated by heating to a temperature T_f^B corresponding to the melting point of the composite layers having the lowest melting point that are present in the multilayers, and the melting point of the alloy after the mixing can be much higher than the initial temperature.

The invention thus enables significant savings to be made in welding processes since it requires less powerful heating means and accelerates the process by reducing the heating time thanks to the rapid release of the enthalpy of mixing H_m.

It is understood of course that the fine multilayer polymetallic composites intended for use as welding metal should be selected from those elements compatible with the parts to be welded. It is possible *inter alia* that the product can be welded onto various parts so as to seal holes or cavities, or quickly repair delicate items

such as jewellery. The materials in accordance with the invention can also be used for microwelding in the electronics industry and in particular in integrated microcircuits.

The following table I gives examples of combinations of the type A-B that can be used according to the invention.

TABLE I

A	B	A	B	A	B
Pd	Sn	Zr	Gu	Au	Mg
Pd	Pb	Zr	Ni	Au	La
Pd	Al	Zr	Au	Cu	Ce
Pd	Mg	Zr	Ag	Ni	Ce
Pd	In	Au	Al	Pt	Sn
Ni	Ti	Ni	Al	Pd	Zn
		Au	Zn	Pt	Zn

The following examples are intended to illustrate the invention without however limiting the scope thereof.

EXAMPLE 1

A composite of the following composition is prepared by co-laminating two strips of palladium and tin

$$Pd_{0.50}Sn_{0.50}$$
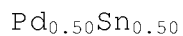
The palladium layer has a thickness of 5 μm and the tin layer has a thickness of 10 μm.

The heat of mixing H_m is 50.16×10^3 J and the heat of fusion H_f is 11.7×10^3 J, and accordingly a surplus energy $H_m - H_f$ of the order of 37.6×10^3 J remains. The specific heat per mole C_p is of the order of 26.3×10^3 J/°C.

The heat released $H_m - H_f = 37.6 \times 10^3$ J/mole thus enables the sample to be heated by $\Delta T \simeq 1400$°C.

By heating a corner of this composite sample to a temperature T of 230°C, which is the melting point of tin, the amount of heat released H_m is sufficiently large and is released sufficiently rapidly so as to consume the whole sample in a fraction of a second, thus producing superheated droplets of liquid alloy. It is found that the heat released H_m is sufficient to provide both the heat H_f and the extra heat needed to superheat the sample to a temperature of at least 800°C, given that the melting point T^{Pd-Sn}_f is equal to about 800°C.

EXAMPLE 2

Another composite $Pd_{01.50}Sn_{0.50}$ is prepared by compressing strips 1 cm wide and 30 to 10 µm thick prefabricated by the technique of liquid impregnation on a cooling roller. In this case too a large enthalpy of mixing is observed, enabling the sample to be superheated to temperatures at least equal to the melting point of the Pd-Sn mixture.

EXAMPLE 3

The single figure shows diagrammatically an application of the composites according to the invention as a fuse.

A composite was prepared by taking as principal conductor a sheet of pure silver (1) about 100 µm thick, 1 mm wide and several centimetres in length, this sheet being placed between two Pd-Sn type multilayers each of the same width as the silver sheet. The alternate layers of Pd and Sn are placed on both sides of the silver sheet in the order shown in the figure, (2) representing palladium and (3) representing tin. It is found that

only two layers of Pd are in contact with the silver
sheet. There are five pairs of Pd-Sn sheets on each side
of the silver sheet. The thickness of the layers of Sn
(3) is about 10 µm per layer and that of Pd (2) is about
5 µm. This gives an overall atomic composition $Pd_{0.5}Sn_{0.5}$
and approximately the same number of moles as in the
silver sheet. The layers and the sheet are tightly
pressed together so as to produce a good thermal contact
throughout. When this sample is integrated in an
electrical circuit by electrical contact at the ends of
the silver sheet, the current passes principally through
the silver sheet and not through the Pd and Sn layers,
which is due to the low resistivity of silver compared to
that of Pd and Sn.

The behaviour of an insulated silver sheet used as
fuse is investigated with respect to the Ag-Pd-Sn
composites, the insulated Ag sheet and that in the
composite having of course the same dimensions and being
incorporated in the same circuit.

Case of the insulated silver sheet

The cross-section A of the silver sheet is about 10^{-3}
and the current I_0 in normal operation of the circuit is
of the order of 10 A. The operational current density is
thus $I_0/A = 10^4$ A/cm^2 of the silver sheet. The heat
released by the Joule effect is 1672 J/s. mole, this heat
being lost in the sheet on account of its surroundings,
so that when $I=I_0$ the sheet heats up by only a few degrees
or ten degrees.

On the other hand when the current increases sharply
as in the case of a short-circuit, that is to say when I
is very much greater than I_0, the heating is more rapid
than the loss of heat to the surroundings and the silver
sheet heats up to the melting point, which is about 960°C,

in a time of the order of

$$\Delta t = \frac{Cp\ T}{P}_f^{Ag}$$

where Cp is the specific heat per mole and is of the order of 25 J/mole ^{o}C. For I = 100 amps t is equal to about 150 milliseconds and for I = 200 amps t is of the order of 40 milliseconds. After this heating time the heat released causes the sheet to melt, accompanied by a sharp increase of its resistivity and thus of P for a heating up to the vaporisation point.

Case of the composite in accordance with the invention

Using under the same conditions the composite product comprising the aforementioned silver sheet shown in the single figure, it is found that when the current increases sharply so that I is significantly greater than I_0, the heating effect is slower to start with since the Pd-Sn multilayers have to be heated through the silver sheet. The melting point T^{Sn}_f of tin is 232°C and the time to reach this temperature is of the order of

$$\Delta t' = \frac{2CpT}{P}_f^{Sn}$$

where the factor 2 is due to the fact that there as many Pd-Sn atoms to heat as Ag atoms. $\Delta t'$ is of the order of 70 milliseconds for I = 100 A and 25 milliseconds for I = 200 A. However, at 230°C the enthalpy of mixing H_m is equal to about 50.16 x 10^3 J/mole, which is released in a time t_m of the order of 2.5 milliseconds. Within the space of about 3 milliseconds this enthalpy of mixing raises the temperature of the whole arrangement comprising the composite and silver sheet by $\Delta T = H_m/2Cp$ equal to 950°C, and the temperature can thus be raised to

the melting point of silver, 960°C, in a total time of 73 milliseconds or 24 milliseconds respectively for I = 100 A or 200 A. It is found that the time required to heat the silver sheet is reduced by half thanks to the use of a composite in accordance with the invention.

It should be noted that the heating is even more rapid on account of the thermal gradient that is established in the sample once the reaction has been initiated, and the liquid phase appearing first of all in the layers that first contact the silver sheet reacts with the silver to form an alloy that in turn sharply increases its resistivity and thus the heat P released per unit time due to the Joule effect and consequently the heating rate.

It is understood of course that this structure can be modified and can be adapted to more complex shapes containing defects, cavities or holes that reduce the cross-section at the chosen sites along the sheet. The use of multilayer composites according to the invention is compatible with this type of modification and ductile and malleable composites can be prepared in any desired shape with initiation temperatures chosen beforehand, particularly in the case where an alloy is used.

EXAMPLE 4

A fine multilayer composite of Pd and In is prepared having the overall composition Pd 0.6 In 0.4, mounted on a thick sheet of silver in series with and arranged after the fuse element of the circuit. In the case of an electrical fault due to a short circuit, it is the fuse element that will cut off the current, whereas if the temperature of the surroundings rises on account of a

fire to T = 156°C, which is the melting point of indium, it is the composite product that interrupts the circuit by rapid release of its heat of mixing H_m = 50.16 x 10^3 J.

EXAMPLE 5

The composite $Pd_{0.50}Sn_{0.50}$ of Example 1 was used as welding material. By heating a small part of the product to a temperature $T = T_f^{Sn}$ = 230°C, a temperature greater than 800°C is reached. Once the alloy has cooled and re-solidified a weld is thus obtained that is resistant to a temperature of 800°C, whereas the composite has been heated only to 230°C.

EXAMPLE 6

The following example is intended to illustrate composites that employ an alloy.

A multilayer composite was prepared as described in Example 1 using a Pd-Au solid solution as layer AA'.

This composite has the following structure:

/ PdAu / Sn / PdAu / Sn

Another composite of type BB' is the composite:

/ Pd / SnIn / Pd / SnIn / Pd / SnIn /

By adjusting the respective proportions of Sn and In, this composite enables the initiation temperature of the exothermic mixing to be chosen.

CLAIMS

1.   Composite comprising fine multilayers, characterised
in that it comprises at least two adjacent layers A-B
each consisting of a pure element A or B or an alloy AA',
BB' such that

(a)   the enthalpy of mixing of the elements or of the
alloys present respectively in the adjacent layers, H_m, is
negative,

(b) $H_m-H_f = Cp \Delta T$, where H_f is the heat of fusion, Cp is
the molar thermal capacity and $\Delta T = T_{max}-T_f^B$ where T_f^B is
the melting point of the element B having the lowest
melting point and T_{max} is the maximum temperature obtained
due to the amount of available heat,

(c) the mixing time t_m is substantially less than the
dissipation time of the heat.

2.   Composite according to claim 1, characterised in
that the thickness of the layers is less than or equal to
150 µm.

3.   Composite according to claim 1 or 2, characterised
in that the elements are chosen from the noble metals,
the transition metals, In, Tl, Sn, Pb, Al, the alkali
metals, the lanthanides, the actinides or their alloys.

4.   Composite according to any one of claims 1 to 3,
characterised in that the elements of one of the layers
are chosen from the noble metals and the transition
metals, and that the elements of the other layer are
chosen from In, Tl, Sn, Pb, Al, Zn, the alkali metals,

Zr, Ti, the lanthanides, the actinides or also alloys of
elements of type A with one another or of type B with one
another.

5.   Composite according to any one of claims 1 to 4,
characterised in that one of the elements is chosen from
Co, Ni, Cu, Zn, Pd, Ag, Pt, Au.

6.   Composite according to any one of claims 1 to 5,
characterised in that the composite of type A-B is a
composite comprising multilayers of type A-B-C-D-A-B-C-D
or also B-A-B-C-B-A-B (periodic) or non-periodic B-A-B-C-
A-B-A-B, in which the elements C and D consist of
materials participating or not in the mixing during the
course of the heating.

7.   Composite according to claim 6, characterised in
that the layer C consists of a material that is inert to
the product A-B at least up to the A-B mixing
temperature.

8.   Composite according to claim 7, characterised in
that the material C is chosen so that it melts by the
release of the heat H_m during the mixing of the layers A-
B.

9.   Composite according to one of claims 1 to 4,
characterised in that the multilayer composite of type A-
B is represented by a composite of structure $(A_nA'_m)$
B $(A_nA'_m)$ B or also $(A_nA'_m)$ $(B_PB'_l)$ C $(A_nA'_m)$ $(B_PB'_l)$ ……….
or $(A_nA'_m)$ or $(B_PB'_l)$ denotes solid solutions of at least

two elements A and A' or also B and B' present in the molar proportions n,m,p,l.

10. Composite according to any one of claims 1 to 9, characterised in that the layers of the composite have a thickness of between 0.1 μm and 150 μm.

11. Composite according to any one of claims 1 to 10, characterised in that the composite comprises layers consisting of superimposed thin sheets A and B or small particles of any arbitrary shape arranged so as to present a contact interface between A and B.

12. Composite according to any one of the preceding claims, characterised in that the multilayers of type A-B are chosen from: Pd-Sn, Pd-Pb, Pd-Al, Pd-Mg, Pd-In, Ti-Ni, Zr-Cu, Zr-Ni, Zr-Au, Zr-Ag, Au-Al, Hf-Au, Au-La, Cu-Ce, Ni-Ce, Ni-Al, Pt-Sn, Au-Ng, Ti-Cu, Pd-Zn, Au-Zn.

13. Thermal primer, characterised in that it comprises at least one composite as defined in any one of claims 1 to 12.

14. Short-circuit fuse, characterised in that it comprises at least one composite as defined in any one of claims 1 to 12, in which the conductor may or may not constitute one of the layers participating in the initiation of the exothermic mixing.

15. Fuse according to claim 14, characterised in that the principal conducting element is sandwiched between the layers of type A-B.

16. Welding alloy, characterised in that it consists of at least one composite as defined in any one of claims 1 to 12.

17. Welding process, characterised in that it employs a composite as defined in any one of claims 1 to 12 and involves heating the composite to a temperature approximately equal to the melting point of the layer having the lowest melting point.